



# Sensing and Awareness in Microsystems

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# Stretchable Electronics – From Hemispherical Imagers to Neural Monitors

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## Summary

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### The Problem:

**Conventional electronics are rigid, brittle and planar, thereby restricting application possibilities**

### The Solution:

**New ways to use old materials enable soft, elastomeric and curvilinear electronics, with performance equal to conventional systems**

### The Opportunity:

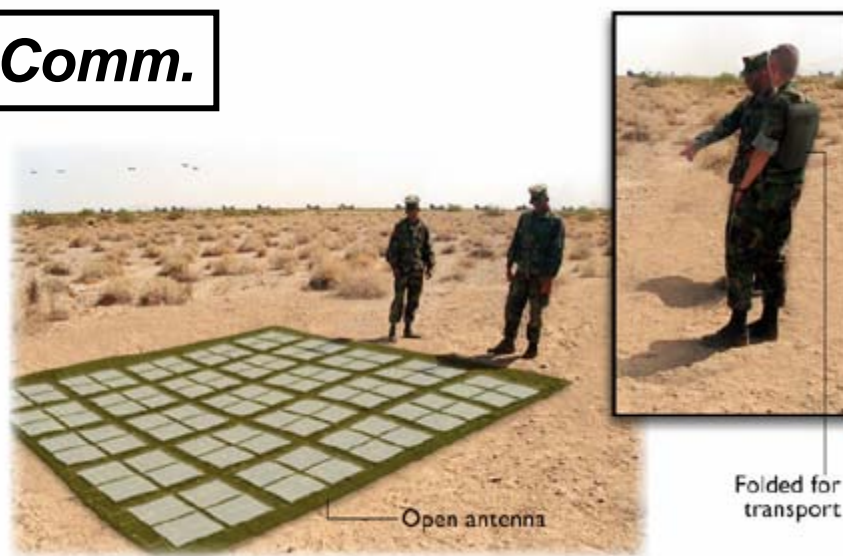
**Stretchable electronics can be used for many new classes of application, with important military implications**

## Stretchable, Curvilinear, Large Area, Rugged *and* High Perf.

### ***Imagers***



### ***Comm.***



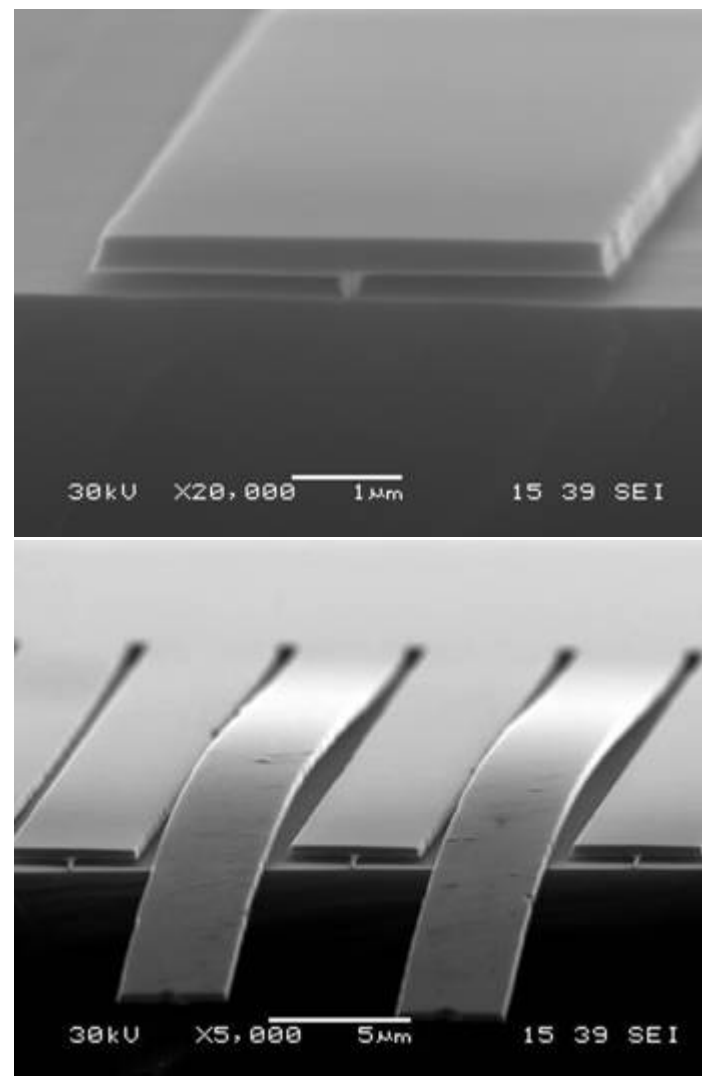
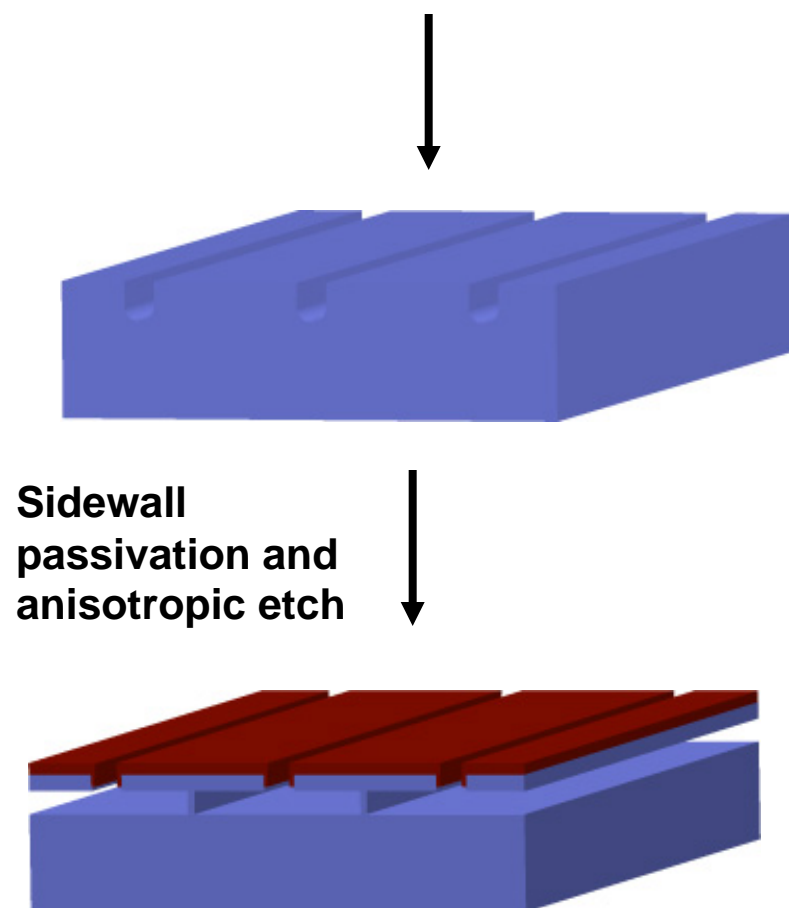
### ***Control***



### ***Struct. Health***

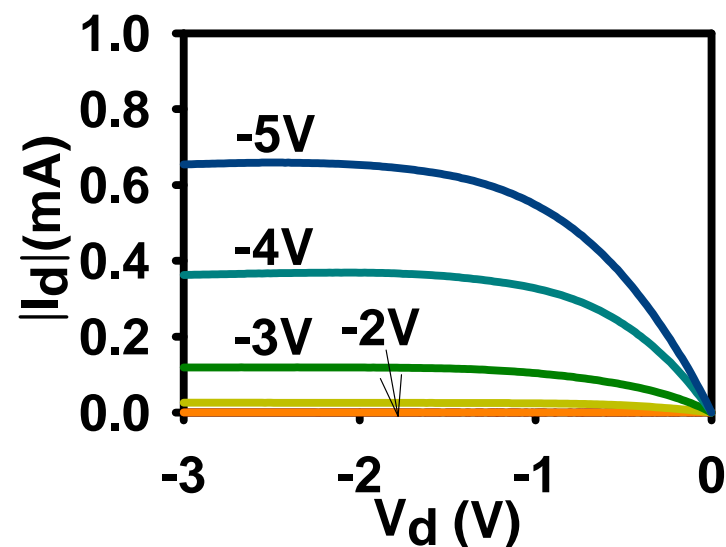
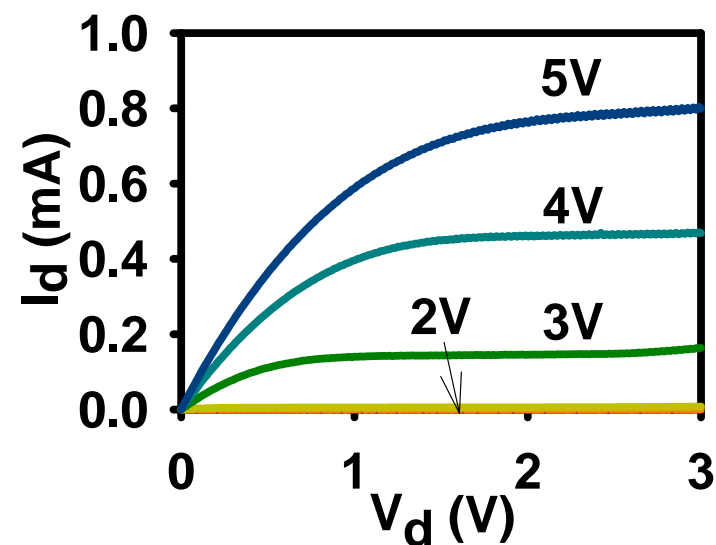
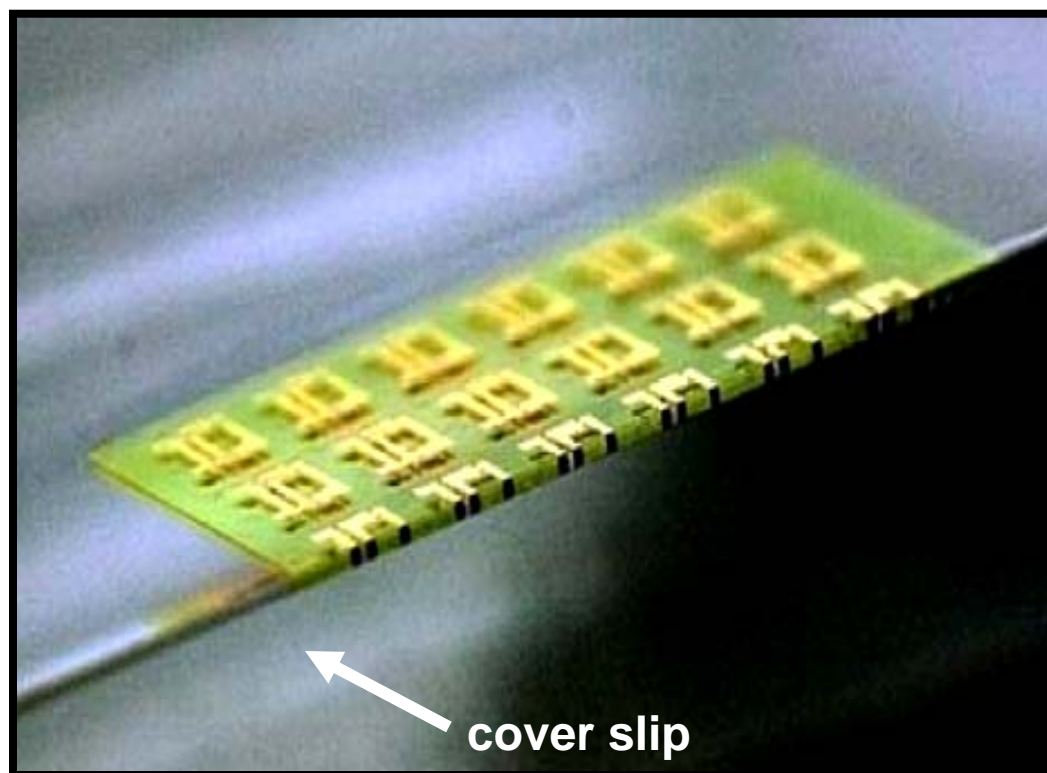


## Si Nanoribbons from Bulk Wafers



*Appl. Phys. Lett.* **88**, 213101 (2006).

## Si CMOS and Extreme Bendability



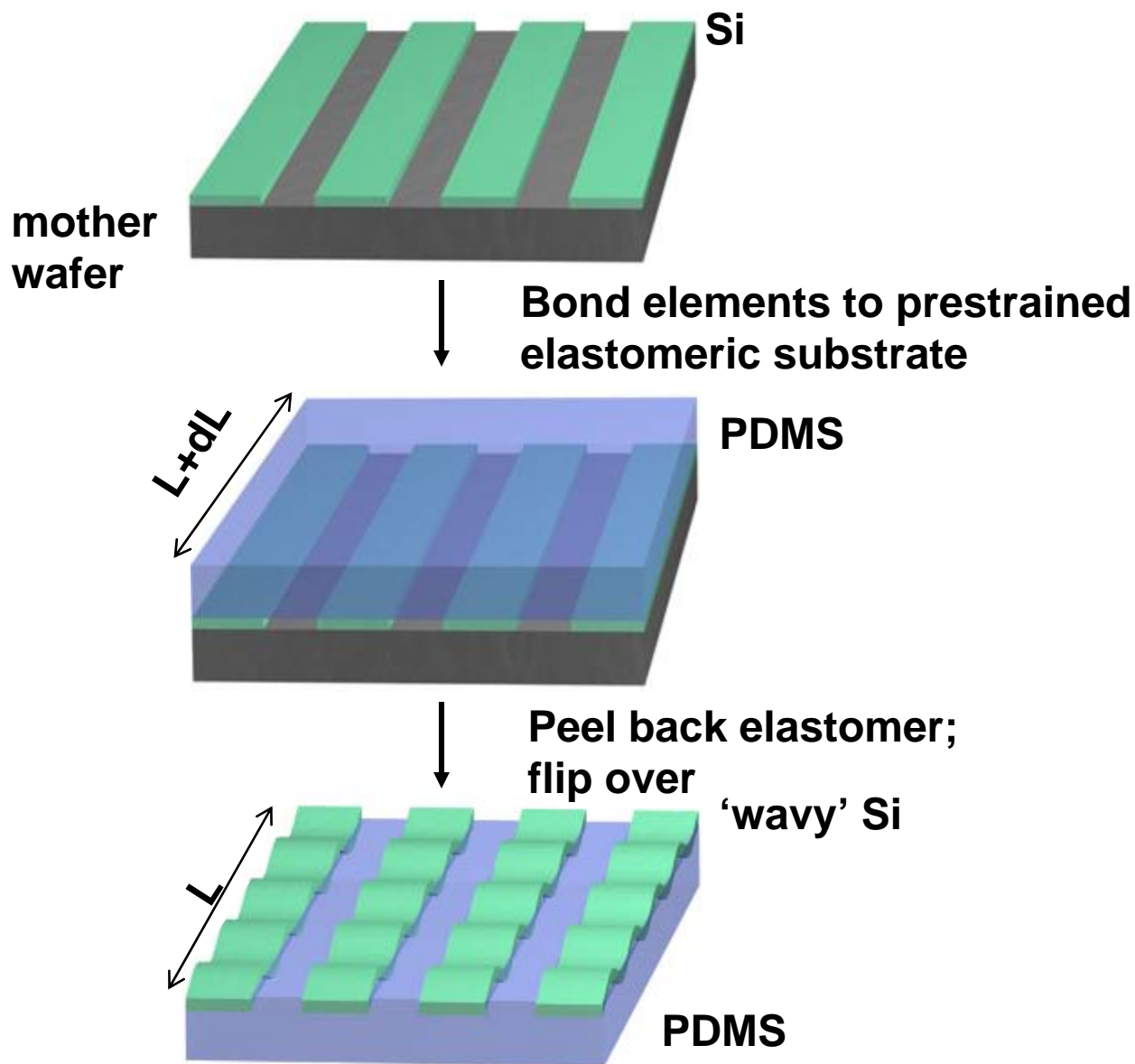
*Adv. Func. Mater.* **18**, 2673 (2008). *IEEE EDL* **29**, 73 (2008).

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*Science* **320**, 507 (2008).

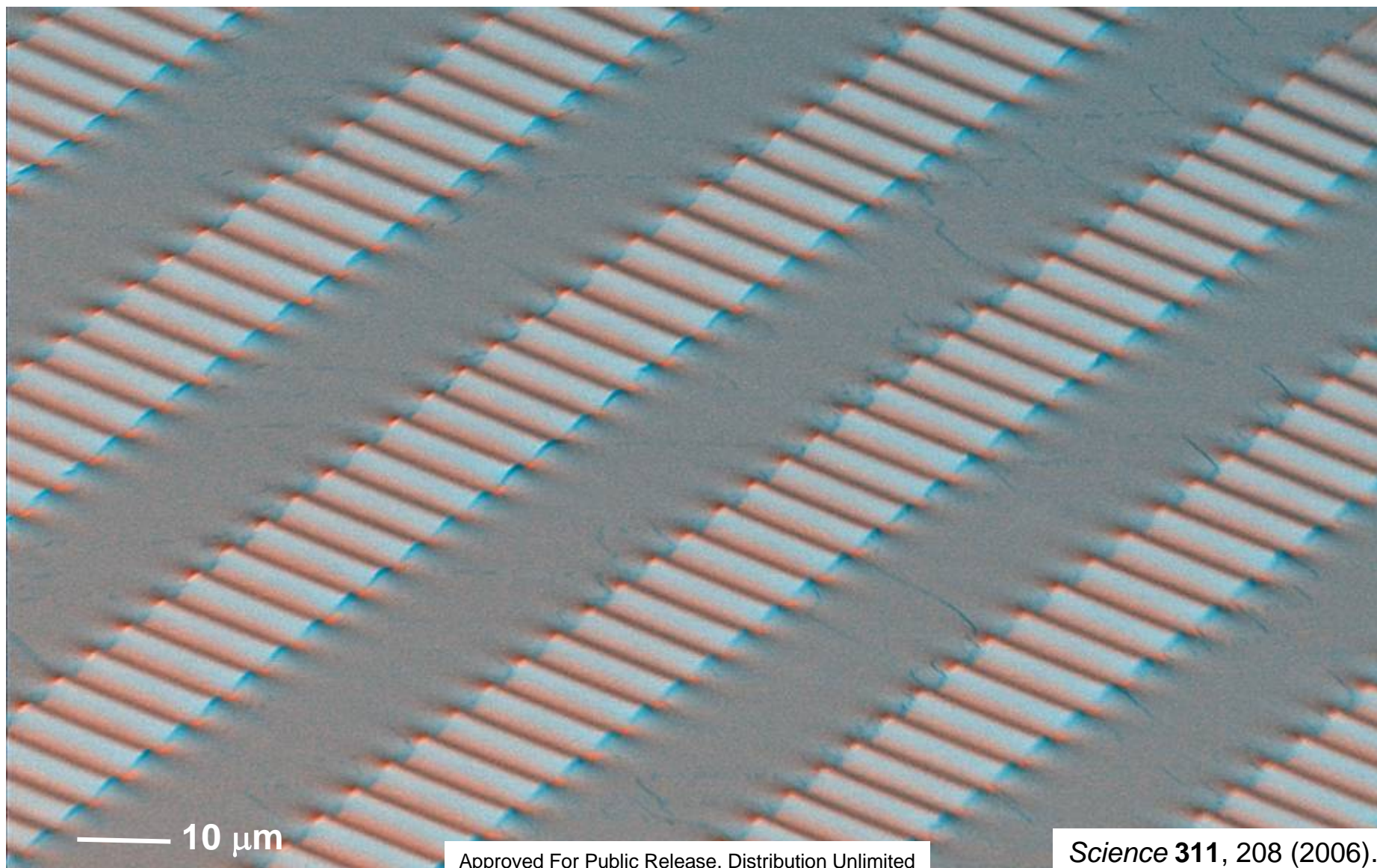


# A Stretchable Form of Single Crystal Silicon





## Stretchable Single Crystal Silicon – ‘Wavy’ Si on Rubber

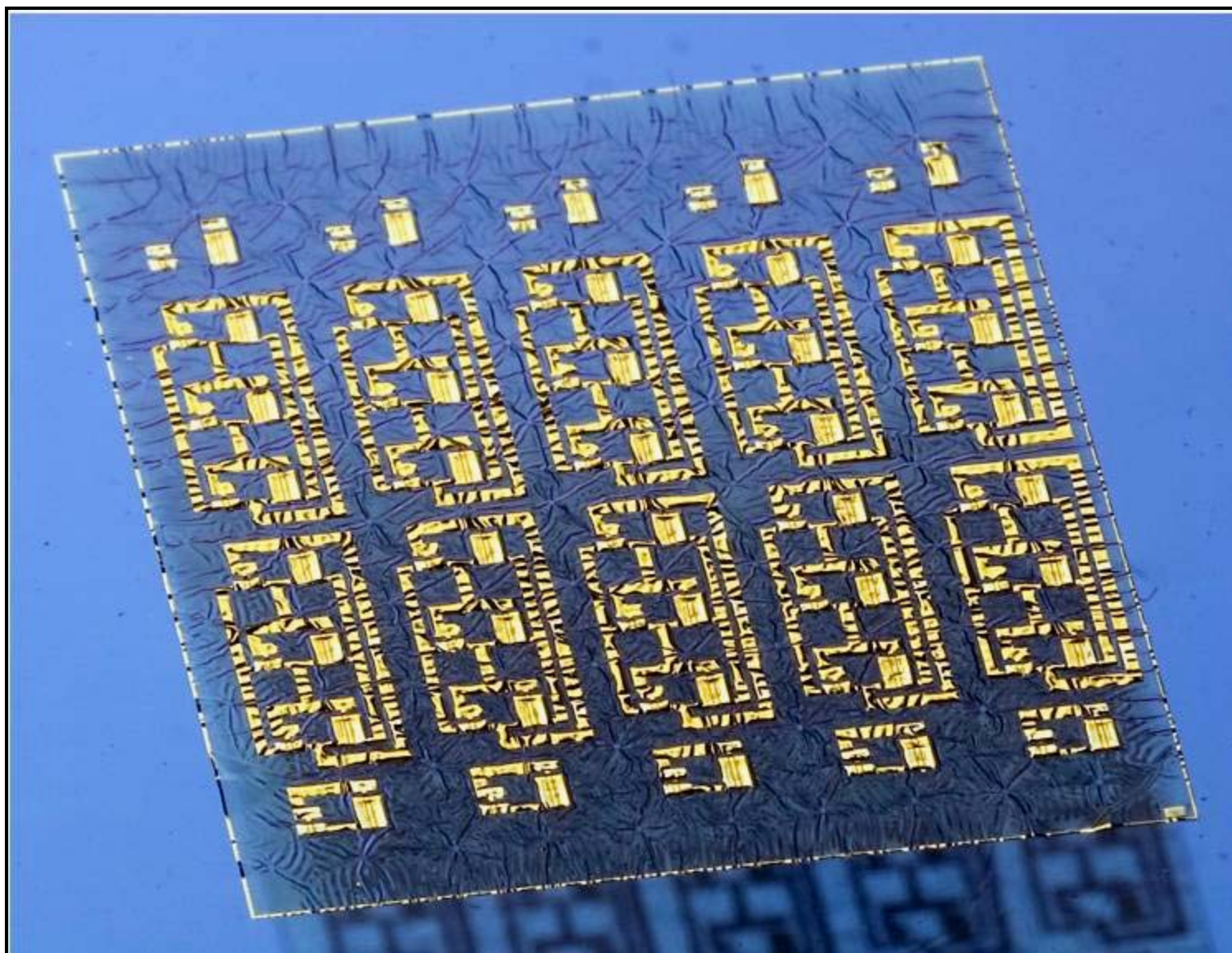


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*Science* **311**, 208 (2006).



## Stretchable Silicon Integrated Circuits

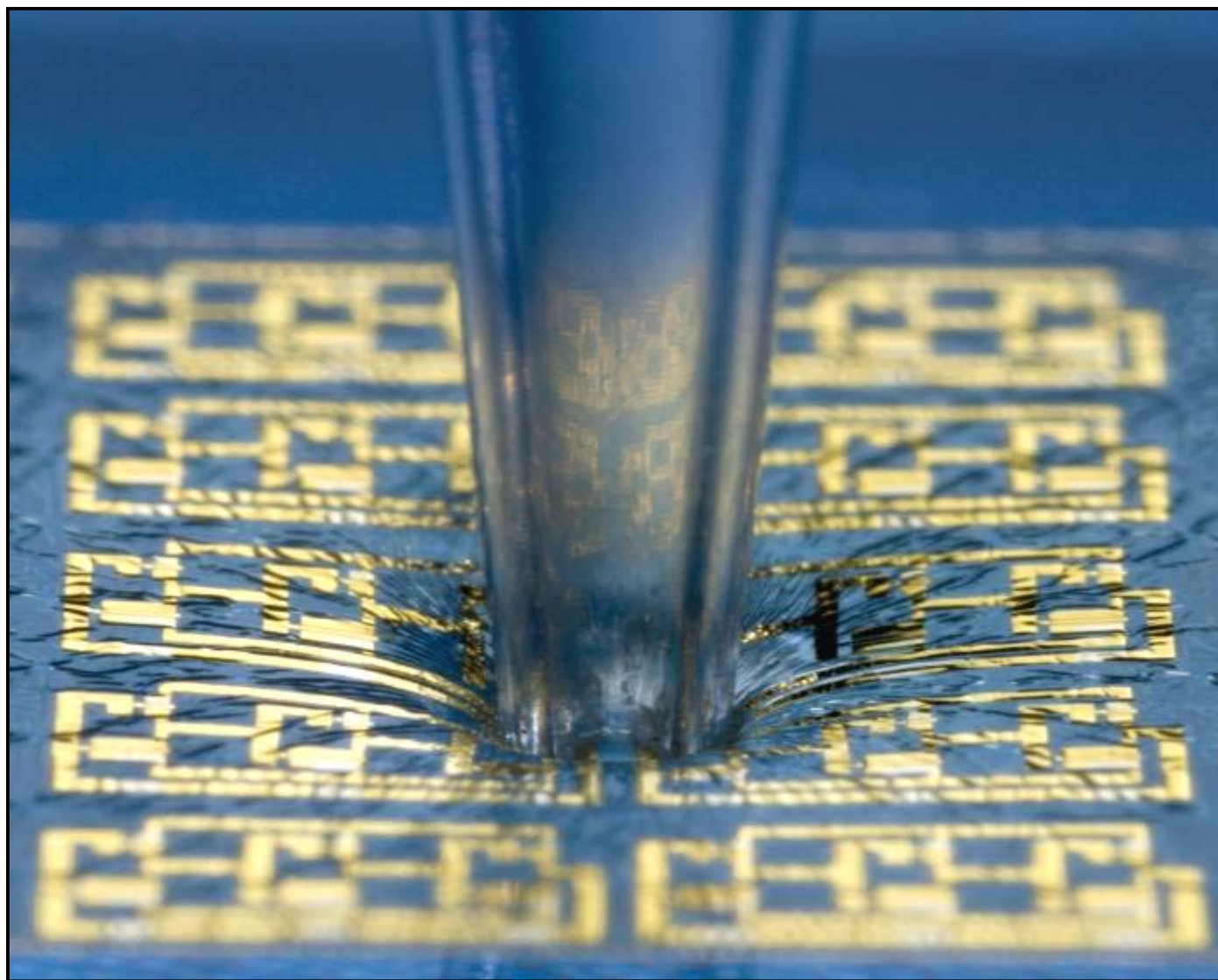


— 0.5 mm

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*Science* **320**, 507 (2008).

## Stretchable Silicon Integrated Circuits



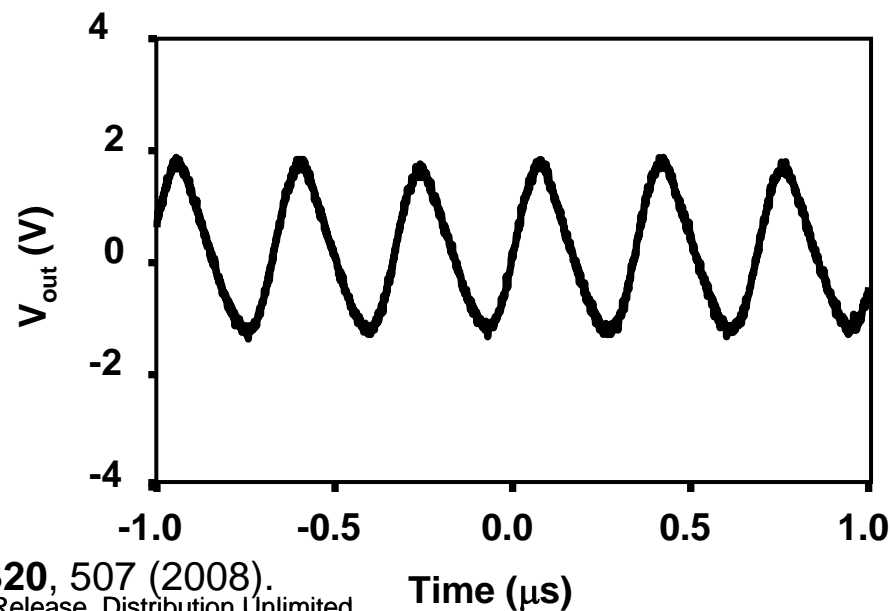
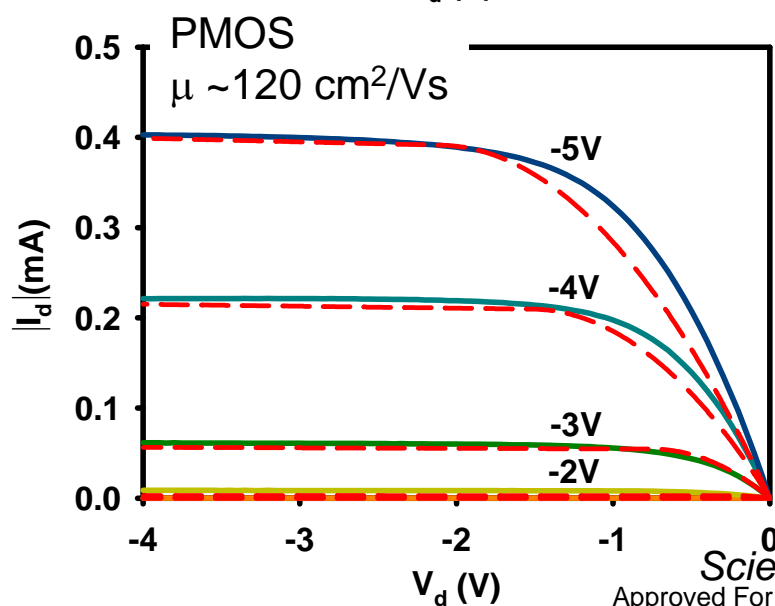
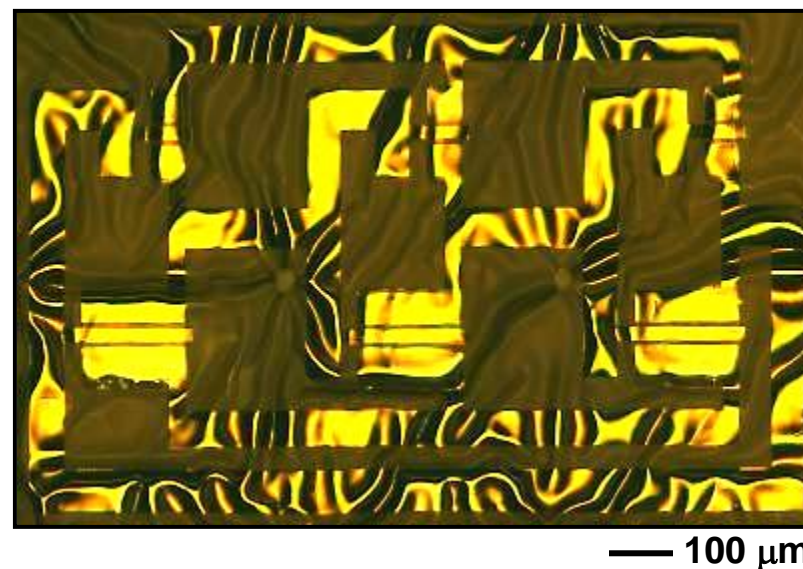
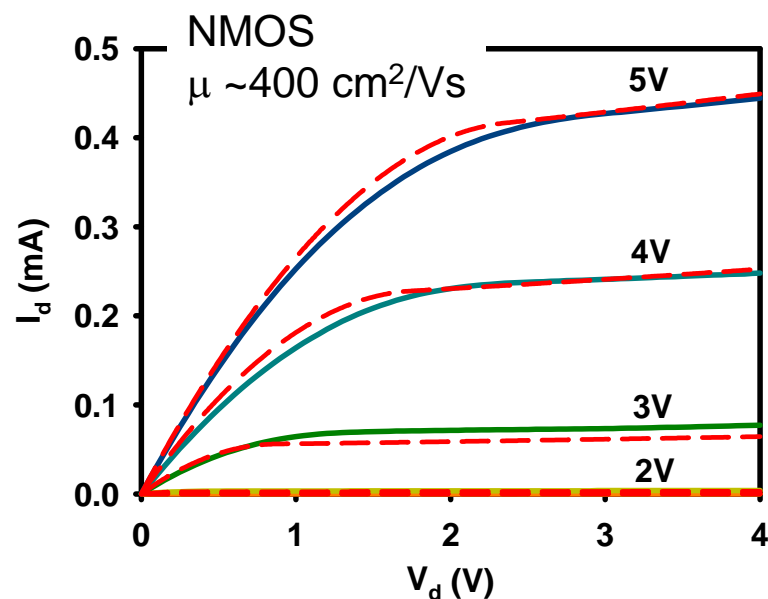
— 0.5 mm

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*Science* **320**, 507 (2008).

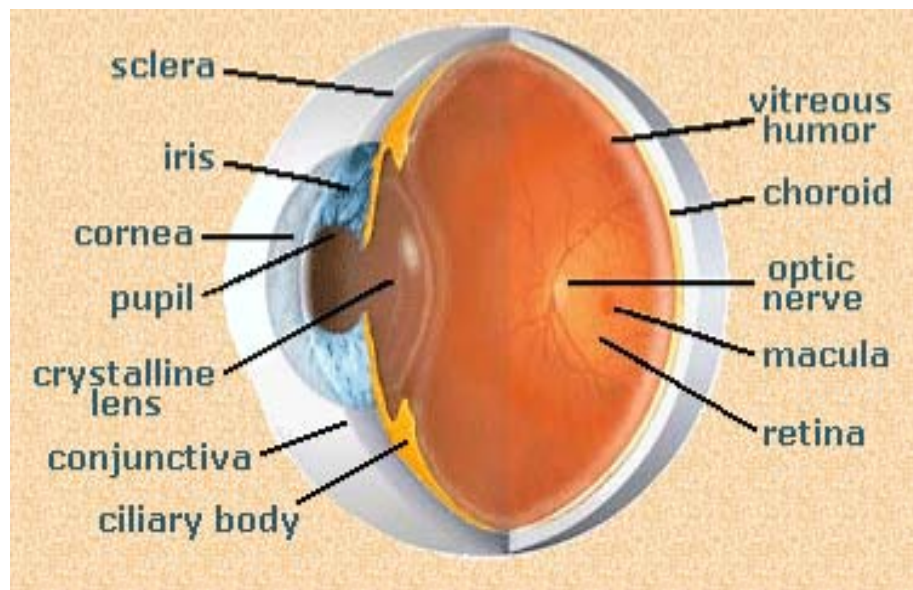


# Stretchable Silicon Integrated Circuits

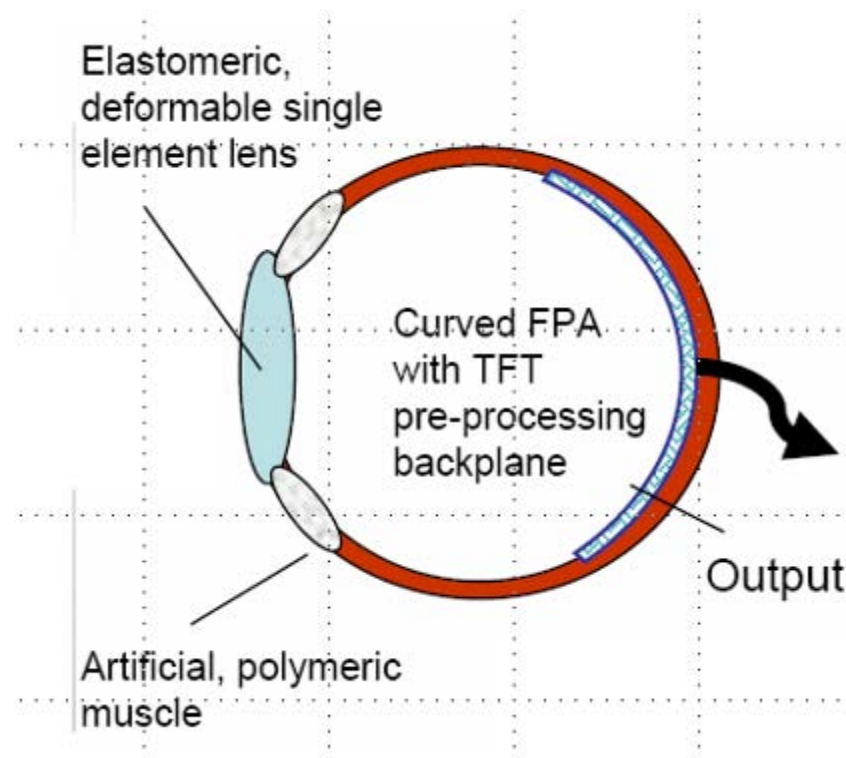


## Curved Focal Plane Arrays for Wide FOV Imagers

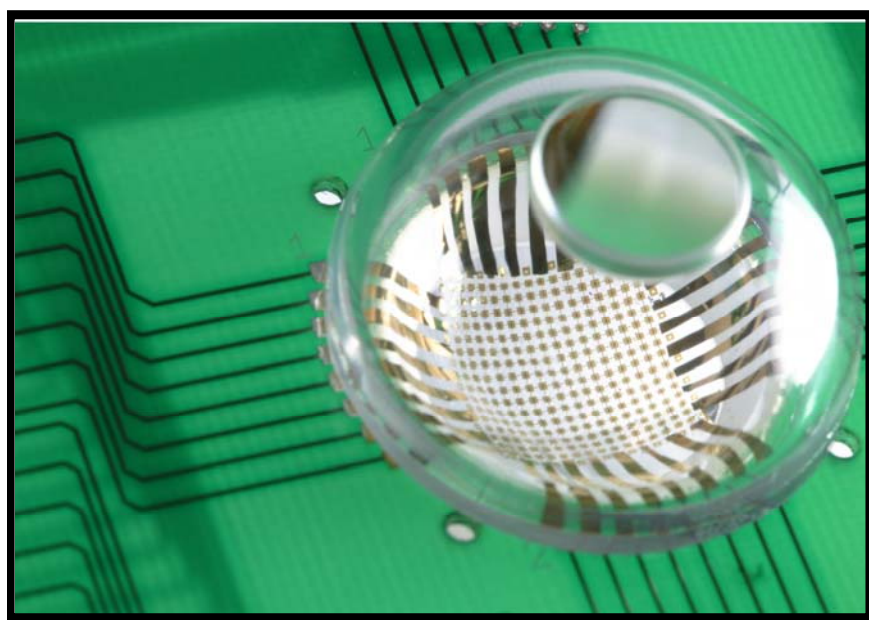
### *Human Eye*



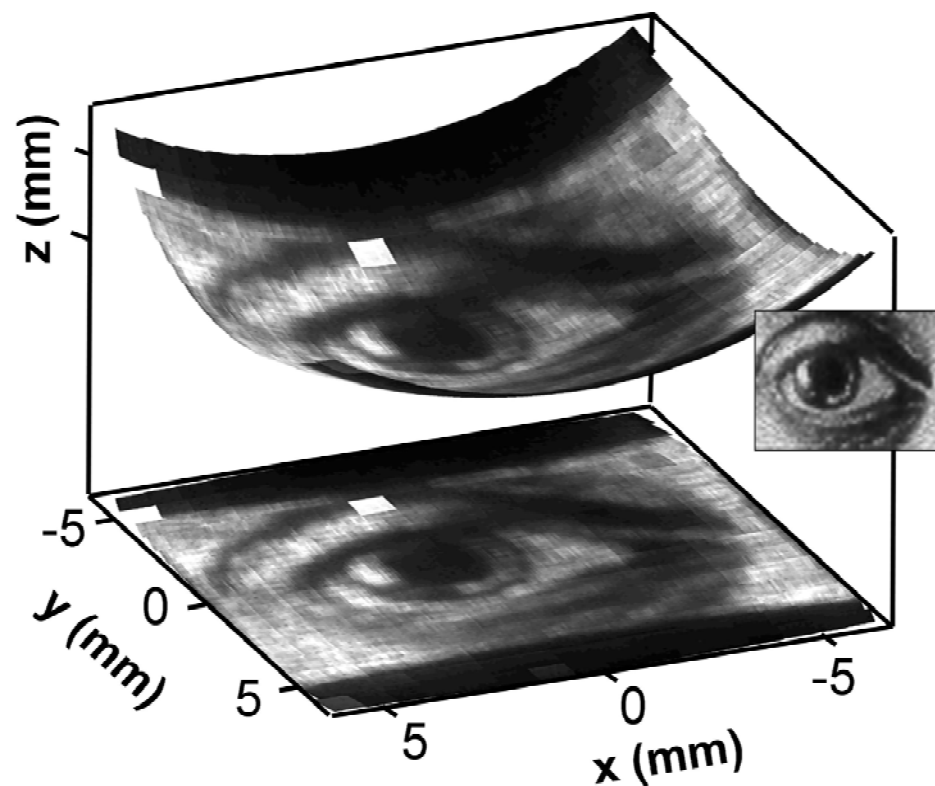
### *Electronic Eye*



## Electronic Eye via Stretchable Electronics



— 2 cm

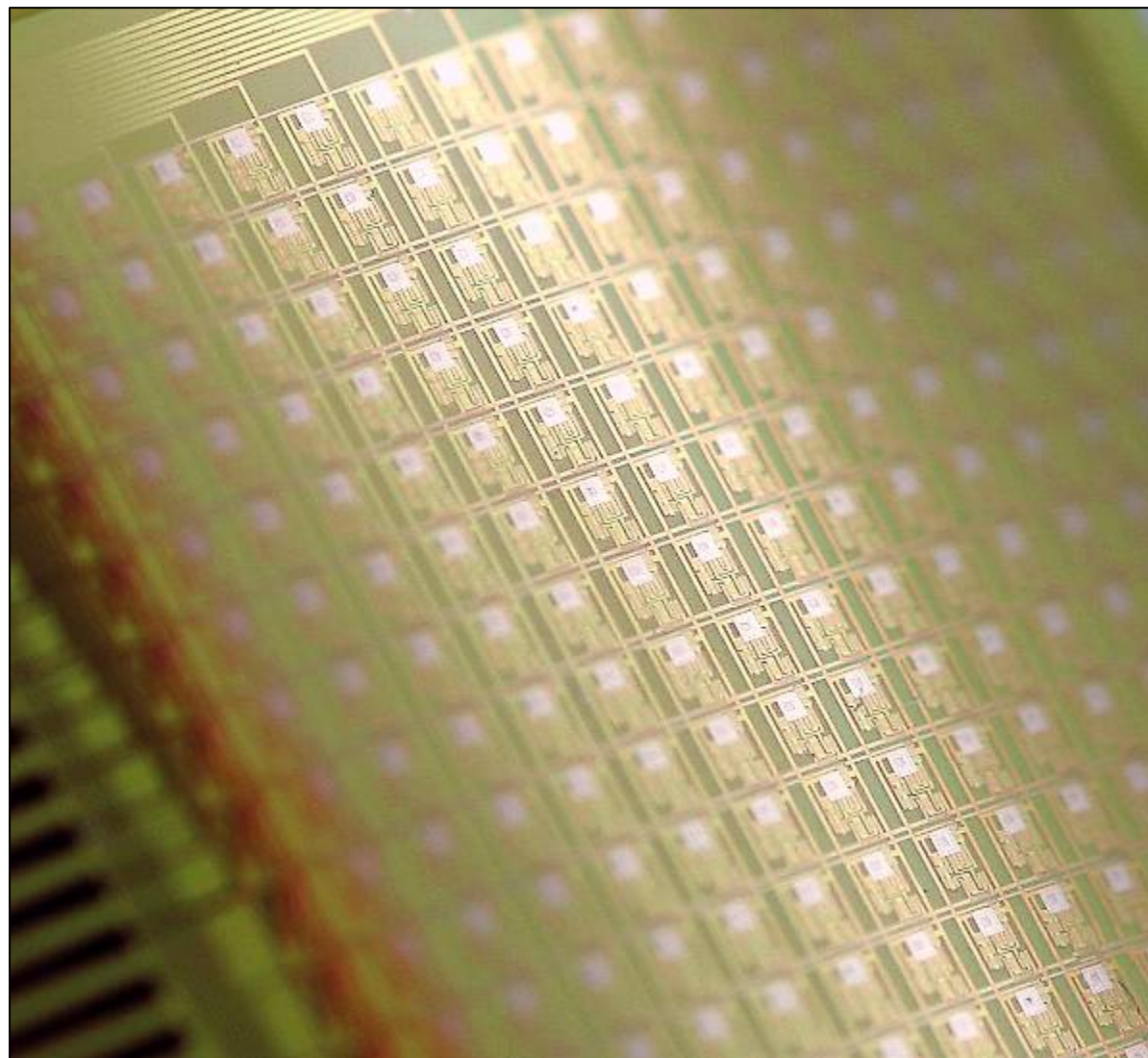


*Nature* **454**, 748 (2008).

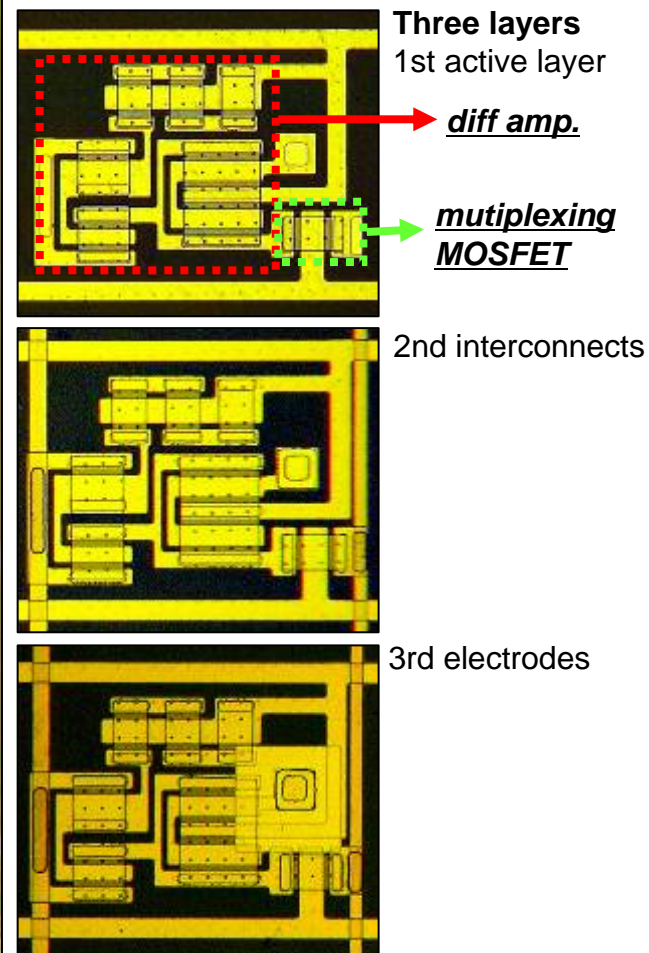
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## Active Neural Sensors – ECoG Tapes (w/ Litt)



- 288 (16×18) Sensor Array
- Multiplexing Capability
- $288 \times 7 = 2016$  transistors



unpublished

1 mm  
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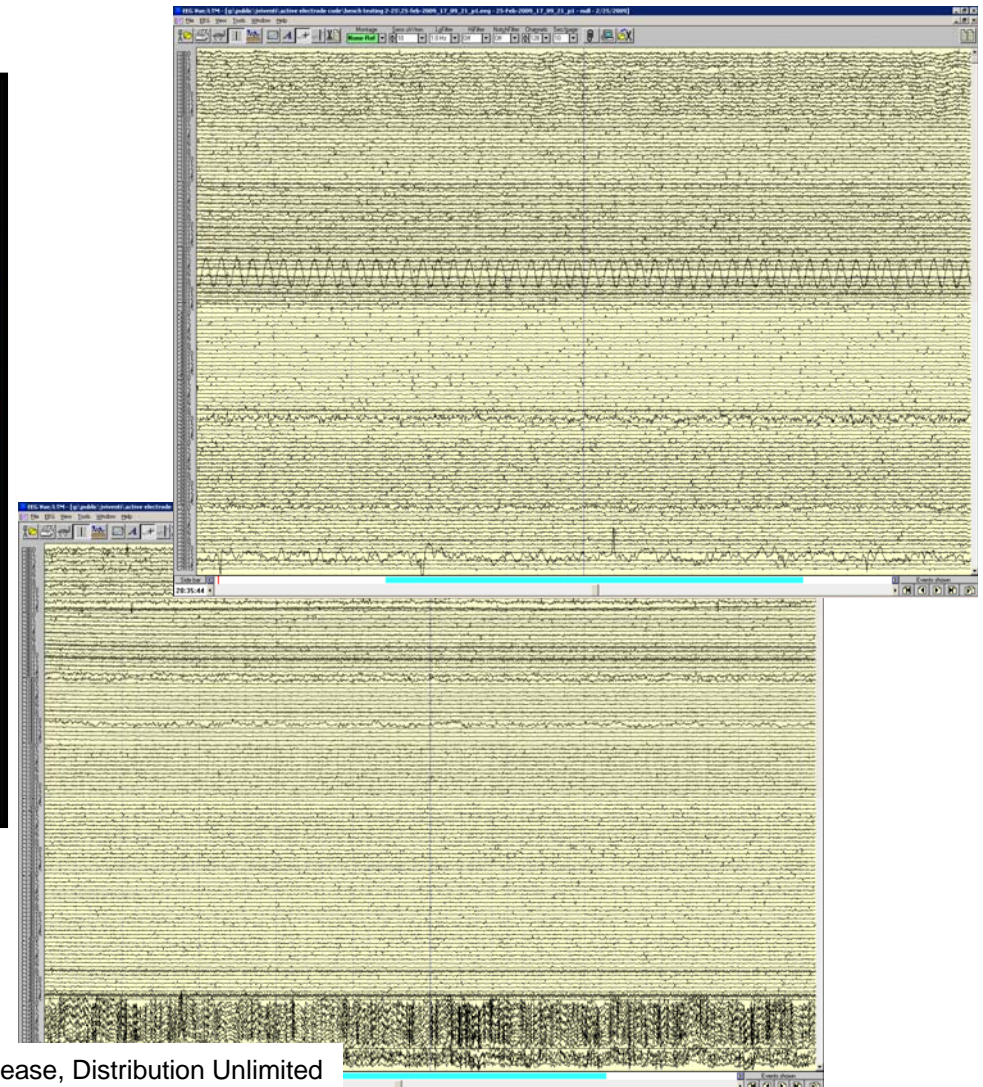
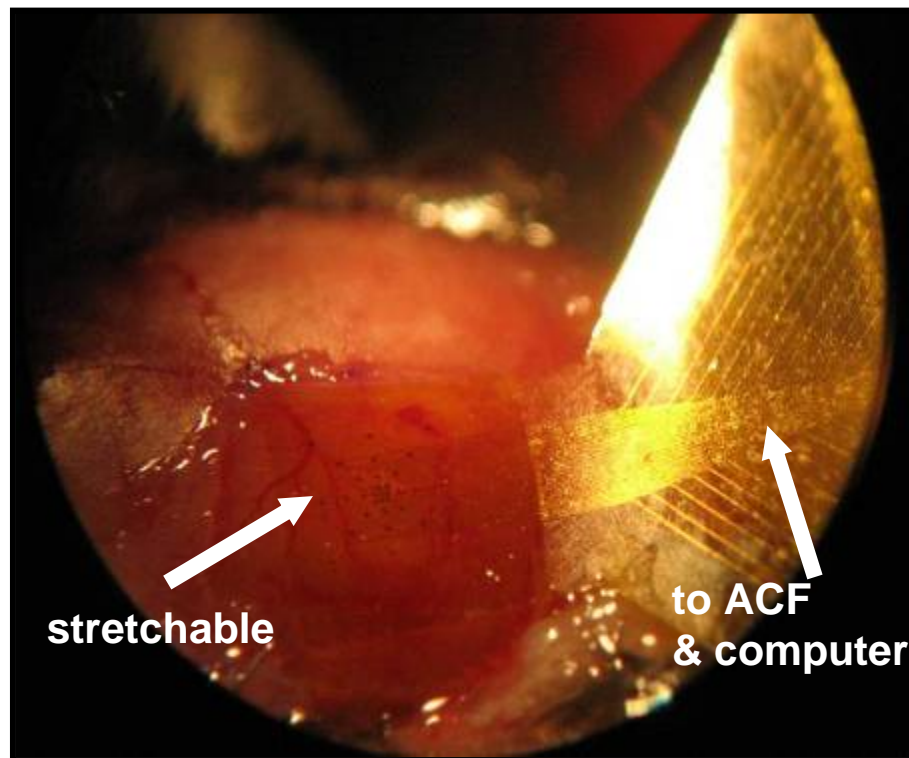
200  $\mu$ m



## Stretchable Electronics for Brain Monitoring (w/ Litt)

256 channels; 500 Hz sampling

### Barrel Cortex in a Rat



unpublished

# **Stretchable Electronics – From Hemispherical Imagers to Neural Monitors**

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**Semiconductor ribbons, membranes represent promising materials for unusual format electronics**

**‘Wavy’ versions of these materials enable stretchable electronics: bio-inspired designs and biomedical devices**

**Electronic eye cameras and neural monitors provide examples**

## ***Senior Collaborators***

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***Prof. Y. Huang (Northwestern) – mechanics theory***

***Prof. P. Ferreira (UIUC) – printer manufacturing systems***

***Prof. B. Litt (U. Penn) – cardiac, neural testing***

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**Northrop Grumman**  
**Intel**

### People





MICROSYSTEMS TECHNOLOGY OFFICE

# MTO SYMPOSIUM

The logo for the Microsystems Technology Office (MTO) Symposium. It features the letters 'MTO' in a large, bold, metallic font. The 'O' is a circle containing a globe with the word 'DARPA' on it. Circuit traces extend from the 'M' and 'O'. Below 'MTO' is the word 'SYMPOSIUM' in a smaller, white, sans-serif font. The entire logo is set against a dark background with a reflection effect below it.

BUILDING THE FUTURE  
FROM THE INSIDE OUT

The background of the poster is a collage of various technological and infrastructure elements. On the left, there's a large satellite dish and a solar panel array. In the center, a complex antenna structure is visible. On the right, there's a detailed view of a ship's deck with various equipment. The entire background is overlaid with a blue grid pattern and a network of lines and nodes, suggesting a global or interconnected system.

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